3.6.7. Introduction to Advanced Coupled Global Positioning System/Inertial Navigation System Test Techniques

As mentioned in Chapter 1, only the most rudimentary form of the coupled global positioning system/inertial navigation system test techniques are presented in this book. Chapter 1 details the reasons for this format; however, in many applications, more rigor, accuracy and documentation of results are required. Table VI outlines additional instrumentation and assets which are typically applied in these more advanced tests. The purpose of this table is merely to emphasize the existence of these advanced techniques. Further, this list is not exhaustive. Many innovative uses of assets and instrumentation exist. It is hoped that the examples provided leave the reader with a taste of how the test can be made more rigorous through the judicious use of instrumentation. In application; the user must refer to the more advanced documents referenced in Chapter 1 or solicit help from more experienced testers.

Table VI: Additional Assets or Instrumentation for use in Advanced Coupled Global Positioning System/Inertial Navigation System Tests

Test	Additional Asset or Instrumentation	Purpose/Benefit
Initialization and Alignment.	Digital recording of navigation data bus to include all Inertial Navigation System (INS) and Global Positioning System (GPS) outputs, GPS initialization and INS alignment parameters and operator actions and inputs. Precisely surveyed alignment location and boresighted aircraft heading and orientation.	Entire initialization and alignment process is captured allowing isolation of poor alignment performance. Initialization process is recorded and correlated to operator selections. Final initialization and alignment results are compared to known alignment location and aircraft orientation.
Static Position Accuracy.	Digital recording of INS and GPS derived position and rates as well as GPS satellite selections. Calibrated, ground based GPS receiver. Video recording of display. Precisely surveyed alignment location.	Digital position and rates are compared to the known static values. Satellite selections and position calculated by calibrated, ground based GPS receiver are examined if GPS accuracy is a problem. Display output to the operator is compared to the direct INS output.

Table VI: Additional Assets or Instrumentation for use in Advanced Coupled Global Positioning System/Inertial Navigation System Tests

Test	Additional Asset or Instrumentation	Purpose/Benefit
Dynamic Non-maneuvering Position Accuracy.	Digital recording of time stamped aircraft rates and precise space positioning data, INS and test GPS derived time stamped position and rates, GPS satellite selections, system modes and operator actions. In some cases, particularly when the filter algorithms are in development, the inputs to the filter are digitally recorded. Video recording of the display.	The profile is flown without the necessity of surveyed point flyovers. Space positioning data and aircraft rates are continuously recorded and later compared to INS and GPS derived values. If derived from a range, the profile is often constrained geographically. A second GPS, of known performance, can sometimes be used with sufficient accuracy to avoid constricting the profile. Recorded aircraft dynamics are also examined to correlate maneuvering excursions with changes in INS and coupled GPS/INS drift rates. When the GPS accuracy is degraded, the satellite selections are examined for anomalies. System modes (for instance when the system degrades to an INS only mode when satellite tracking is lost) are verified for their appropriateness. The inputs to the GPS/INS filter are sometimes needed to develop and verify the filter weights. The display video is compared to the INS/GPS bus data to check for inconsistencies caused by the manipulation of the INS data and then its display.
Dynamic Maneuvering Position Accuracy.	As for the Dynamic Non-maneuvering Position Accuracy test.	Typically, precise space positioning data is derived from an instrumented range. Aircraft dynamics can be derived from either on or off the aircraft. The INS/GPS derived rates and position are compared directly with the time correlated data as the maneuvers are performed. When the GPS accuracy is degraded, the satellite selections are examined for anomalies. System modes (for instance when the system degrades to an INS only mode when satellite tracking is lost) are verified for their appropriateness. The inputs to the GPS/INS filter are sometimes needed to develop and verify the filter weights. The display video is compared to the INS/GPS bus data to check for inconsistencies caused by the manipulation of the INS data and then its display.

Table VI: Additional Assets or Instrumentation for use in Advanced Coupled Global Positioning System/Inertial Navigation System Tests

Test	Additional Asset or Instrumentation	Purpose/Benefit
Navigation Performance in Overwater /Multipath Environment	Digital recording of the data derived from each receiver channel if possible.	If possible, the output of each receiver channel is recorded and compared to a calibrated, ground based GPS of known characteristics to check for the presence of multipath phenomenon. This is often not practical due to system architecture and multipath is inferred by recording the parameters listed for the Dynamic Maneuvering Position Accuracy test. The data is then analyzed for the multipath induced, characteristic loss of accuracy and variances in satellite quality while flying the aircraft to induce the multipath phenomenon.
Mission Utility and Integration.	As for the Dynamic Non-maneuvering Position Accuracy as well as the Navigation Performance in Overwater/Multipath Environment tests.	This test requires the largest amount of data to completely document the results. It is during this test that most of the unexpected problems are found. In anticipation of having to document these deficiencies, maximum instrumentation and range support are sometimes brought to bear in case unforseen data are required in post-flight analysis.

4.0. ELECTRO-OPTICAL SYSTEM TESTING

4.1. Introduction to Electro-Optical Theory

4.1.1. General

Figure 12 depicts the electromagnetic spectrum [Ref. 37:pp. 2.1a,2.82a]. The portion of the spectrum applicable to Electro-Optical (EO) systems lies between the Extremely High Frequency (EHF) band and the X-ray band [Ref. 37:p. 2.1]. EO systems are very similar in concept to their RF band counterparts including the radars discussed earlier; however, they have some unique strengths and weaknesses. Due to their extremely high frequencies and small wavelengths, the bandwidths of EO sensors are extremely high, and very narrow beamwidths are possible, providing highly accurate systems, capable of imaging. Narrow beam widths make EO systems hard to jam. [Ref. 37:p. 1.1].

Common applications of EO systems include [Ref. 37:p. 1.1] (Note that there is an RF counterpart to each application):

Threat Detection, Identification and Tracking
Threat Detection and Warning
Surveillance and Ground Mapping
Navigation
Communications
Weapons Delivery
Direct Radiation Weapons

For the purposes of demonstrating the thought process used for developing EO test techniques, this book will concentrate on passive systems, since these systems are perhaps the most unique of the EO category of avionics.

4.1.2.Infrared Systems

A large majority of EO systems operate in the near, middle and far InfraRed (IR) band. Additionally, the test techniques used to test IR systems are similar to the techniques used to test all EO systems. For these reasons, a sample IR system will be used to demonstrate the procedure used to develop all EO test techniques. The generalized thought process may then be applied to develop tests for specific systems.

All objects above a temperature of absolute zero emit within the IR bandwidth. The amount and frequency of the IR radiation emitted varies with the temperature of the object [Ref. 74:Chap. 3]. When operating, most military targets are strong IR emitters due to their high temperatures.[12] This is perhaps the greatest advantage of the IR EO system since it allows passive detection and imaging of militarily significant targets. [Ref. 37:p. 1.1]. The universal emittance of IR radiation also accounts for one of the most significant weaknesses of IR systems. Since all objects radiate IR at some level, a large amount of clutter exists in the IR environment from which the system has to discriminate the target. Another important disadvantage of IR systems is the strong level of atmospheric absorption and scattering of IR radiation. IR systems generally operate over much lesser ranges than RF systems due to this constraint. [Ref. 37:p. 1.2; Ref. 74:Chap. 4-5]. Finally, IR systems are strictly limited to line of sight propagation paths. [Ref. 37:pp. 1.1-1.2].

4.1.2.1. Discriminating Targets from Clutter

The discrimination of IR targets from background noise can be accomplished through a number of techniques. Wavelength/frequency (the frequency of the emitted radiation is dependent upon the emitting object's absolute temperature) can be used as a discriminator. This concept is known as chromatic filtering. [Ref. 37:p. 2.35; Ref. 74:p. 17.35-17.47, 22.95-22.10].

As illustrated in figure 3, the RF spectrum of a radar signal can be completely described in the amplitude versus frequency domain by breaking the spectrum into its Fourier components. The EO analogy is to break the IR or visual (or any other band) scene into Fourier components in the spatial fre-

[12]Some military targets can be purposely cold-soaked to make them harder to detect. For instance, a visually hidden tank can be shut off for days, making its temperature close to ambient. The tank can still be detected with a system which resolves the fine IR variations caused by differences in the heating/cooling rates of the steel tank versus the surrounding environment.

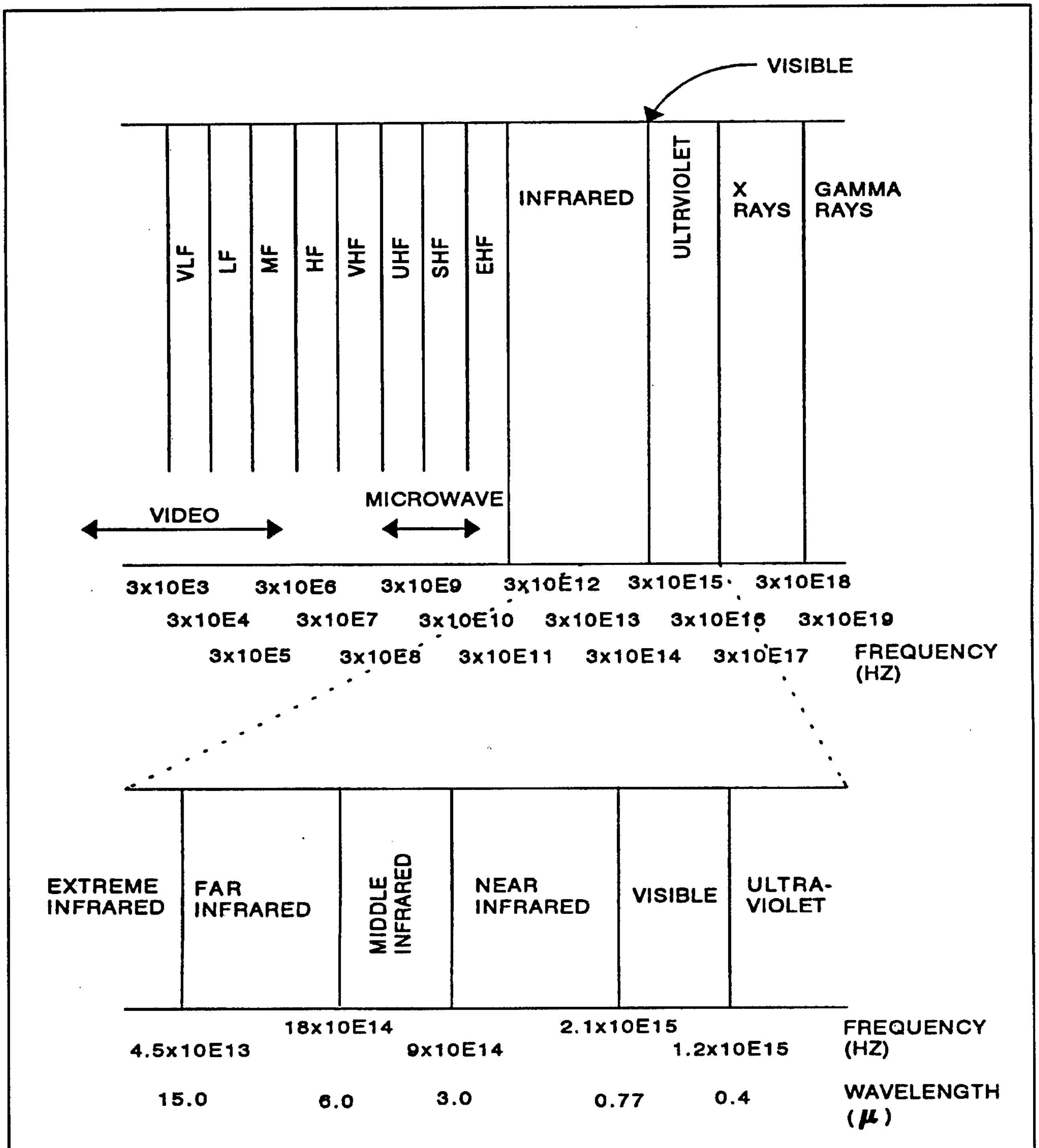

Figure 12: The Electromagnetic Spectrum [Ref. 37:pp.2.1a, 2.82a]

quency domain. Spatial frequency can be visualized as the number of times a component of a physical shape occurs over a unit of measurement. Normally, for EO systems, the units used are angular. As a simplistic example, a picket fence could be modeled with a single spatial frequency that describes the number of pickets per radian of scene. A tank, ship or series of objects, require a number of discrete Fourier components to be adequately described in the spatial frequency domain. The components can be filtered to eliminate unwanted features and thus the signal to noise characteristics of the sensor can be improved. Following filtering, the components are re-combined to present the filtered scene. [Ref. 37:pp. 2.36-2.39]. As an